Evaluation Of The Hydroenergetic Potential Of The Fall From Kalako To Dabola, Guinea.

Doussou Lancine TRAORE, Yacouba CAMARA, Ansoumane SAKOUVOGUI, Mamby KEITA

Polytechnic Institute, Gamal Abdel Nasser University of Conakry - Guinea,
Energy Department, Higher Institute of Technology of Mamou - Guinea,
Department of Physics, Faculty of Sciences, Gamal Abdel Nasser University of Conakry - Guinea,
Traoredl54 @ gmail.com, +224 628 991426
cyacouba90@gmail.com, +224 622288295
ansoumane2015@gmail.com, +224 628016168
mamby1952@gmail.com, +224 622681932

Abstract: The hydro-energetic potential of the Kalako site on the Tinkisso River in Dabola prefecture, evaluated by the spot measurement method during the month of March (dry season) is 5085.50 kW, or about 5.1 MW. This value is in the range of mini hydroelectric plants. The values of the evaluation parameters of this hydroenergetic potential at this time are: the depth of the watercourse (0.58 m), the flow velocity (1.46 m/s), the flow rate (14.4 m^3/s), the drop height (60 m) and the efficiency of the electromechanical equipment (60%). Such a regular assessment of the hydroelectric potential of all waterfalls available in the country would provide a reliable database on the existing hydroelectric potential, hence the objective of this research.

Key words: Assessment, potential, hydropower, useful power.

1.Introduction

Hydroelectric power is a renewable energy obtained by converting the hydraulic energy of the various natural water flows into electricity. The kinetic energy of the water flow is converted into mechanical energy by a hydraulic turbine, then into electrical energy by an alternator. Electricity is a final form of energy that contributes greatly to the quality of life of people and the economic development of nations, because of its ease of use and the multiplicity of its uses. Hydropower alone accounts for more than 94% of global renewable energy generation (Williamson et al., 2014). It is the first renewable source of electricity production used in Guinea (Innovation Energy Development, Guinea, 2015) and, worldwide, it is the third source of electricity production (16.6% in 2014 or 3900 TWh) behind coal (40.6%) and gas (22.2%) (Mitigation, 2011). In the current context of regulation and liberalization of the electricity market, the questions and concerns about the environmental consequences of the production of electricity using fossil or radioactive fuels have triggered a real enthusiasm in recent years for the use of renewable energies as evidenced by numerous research articles. In 2011, hydropower is accounted for approximately 16.2% of global electricity generation and has many strengths. It is a renewable energy, low operating cost and is responsible for low greenhouse gas emissions. Another advantage is that it is virtually independent of the price of fossil fuel markets. However, it has social and environmental disadvantages, particularly in the case of dams established in non-mountainous areas: population displacements, possible flooding of agricultural land, changes in aquatic and terrestrial ecosystems, blockage of alluvium, etc. (Sukvipool, 2012). Humans used water mills powered by paddle wheels to grind wheat for over two thousand years. In the 19^{th} century, paddle wheels were used to produce electricity and were replaced by turbines. In the 1920s, a rapid expansion of electricity was born in France, with an increase by eight in the production of hydroelectric power thanks to the first dams. In 1925, Grenoble organized the international exhibition of the white coal. China, Canada, Brazil and the United States are the largest producers of hydroelectricity. The assessment of these hydroelectric potentials is often based on analyzes of meteorological and hydrological data over a long period (25 to 50 years). It turns out that for most of these sites in Guinea, these data are unavailable. Large hydropower plants (86%), are hydroelectric power plants with high power (greater than 10 MW) and small hydropower plants (8.3%) are those with a power of less than 10 MW. This second category of hydropower plants is generally subdivided into small, mini and micro centers. Mini-hydropower plants (small-scale) have an installed capacity generally less than 5 MW. They consist mainly of upstream and downstream tanks, a balance chamber, a penstock, a hydraulic turbine, an alternator and a diffuser. Four characteristic quantities make it possible to evaluate the importance of the hydroelectric installations: the flow of equipment or the maximum flow likely to be turbined by the power station, the height of fall or the difference in altitude exploited, the power of the development and the produced electrical energy (Kifumbi, 2018). In the Republic of Guinea, the supply of electricity is still a major issue throughout the country, especially in rural areas. However, the hydropower potential of Guinea is enormous, 6000 MW, with a very dense hydrographic network (1165 streams), which has its origin mainly in the two mountainous regions of the country, the Fouta-Djallon and Forest Guinea. To date, only 2% of this potential is developed and benefits only 8% of the Guinean population (Global Water Initiative-West Africa, 2017). The Guinean electricity system relies mainly on hydroelectric power, which represents 58% of the total installed power, and on thermal energy. The first interconnected system, which serves the highest concentration of users and extends from Conakry to Labé, is supplied by: the Kaleta hydropower plant (240 MW) with maximum power, but which drops below 70 MW during the period of low water; the Garafiri hydroelectric plant (75 MW) of installed capacity; the Grandes Chutes hydroelectric generating station (27 MW); the Donkéa hydroelectric plant (15 MW); the Banéa hydroelectric plant (5 MW); Kinkon hydroelectric generating station (3.4 MW); the K-Énergie thermal power station (75 MW including 25 MW available); the Kaloum 1 thermal power plant (24 MW); the Kaloum 2 and Kipé thermal power plants (26 and 50 MW) and the Kaloum 3 and 5 thermal power plants (77.2 MW). A second interconnected system is located in the center of the country. It is powered by the Tinkisso hydroelectric power station (1.65 MW) and the Faranah thermal power station (1.4 MW). This system serves the cities of Dabola, Faranah and Dinguiraye, where is also located a thermal micro-power of 160 kW. The other components of the country's electricity system are: 11 isolated centers in the west and east (Boffa, Gaoual, Télémélé, Lélouma, Kissidougou, Kouroussa, Boké, Kankan, Kérouané, Macenta and N'Nzérékoré), powered by diesel generating 10.14 MW in total (only those from Kankan, Boké, Macenta and N'Nzérékoré are currently operational); 2 isolated hydropower plants in Samankou (0.16 MW) and Loffa (0.16 MW) supplying Télémélé in the west and Macenta in the south-east of the country (Innovation Energie Developpement, Guinea, 2015). Based on the standard needs of rural households and socio-collective amenities per village, the annual energy needs of Guinea's rural areas are estimated in the year 2025 at: 65000 toe/year of electrical energy; 98,900 toe/year of cooking and heating energy and a total of 163,900 toe/year (Ministry of Energy and Hydraulics, Guinea, 2012). This research focuses on the assessment of the hydro-energetic potential of the Kalako Falls site in Dabola, on the Tinkisso River in March 2017, using the method of spot measurements of physical and hydrological parameters, with the aim of proposing additional power to the Tinkisso power plant at Dabola generating 1.65 MW.

2. Materials and methods

2.0 Presentation of the study area

The Kalako Waterfall on the Tinkisso River is upstream of the Tinkisso hydroelectric power station in the Upper Guinea prefecture of Dabola (Figure 1). It is bounded on the north by the sub-prefecture of Banko, on the south by the Tinkisso hydroelectric power station, on the east by Souarela village and on the west by the city of Dabola. It is between 11°19 'west longitude and 10°66' north latitude and is at an average altitude of 586 m. The area of its watershed is 850 km^2. The Kalako site is 10 km from the Tinkisso hydroelectric power station. The left slope of the site has a slope of slight inclination, with a bedrock, covered by a small thickness of earth. The slightly altered gneiss appears on the side of the hill on nearly 595 m. The rock outcrops widely in the right bank with a constant hard gneiss-magmatic facies very hard, unaltered (Oumar, 2011). The prefecture of Dabola is located in the center of the Republic of Guinea between the middle and the upper Guinea. It depends on the region of Faranah and is limited to the North by the prefecture of Dinguiraye, to the west by that of Mamou, to the East by that of Kouroussa and to the south by that of Faranah. The city of Dabola is the chief town of the prefecture. The prefecture of Dabola is an administrative subdivision with seven sub-prefectures: Dogomet, Bissikrima, Banko, Kindoye, Kankama, Arfamoussaya and Ndema. The climate of Dabola is of the tropical type, characterized by the alternation of two seasons (rainy and dry). The average temperature in Dabola is 24.5°C. The average annual rainfall is 1528 mm (Oumar, 2011).

Fig. 1.1: *Location of the Kalako site on the Tinkisso River in Dabola Prefecture*

2.1 Materials

As part of this research, the following equipment and materials were used: a float, a stopwatch, a graduated ruler, a decameter, two Current and Propeller currentometers, a GPS (Global Positioning System), a clisimeter, a level, a compass and a telescope on a tripod.

2.2. Methodology

The method for assessing the hydropower potential of the Kalako site in Dabola focuses on measurements of hydrological parameters, namely: stream flow, gross head, net drop, and gross power determination. and useful based on the measurements made. The flow rate of the stream (Q) is a function of the flow velocity (V) and the flow section (S) of the stream. It is calculated by the relation 1.

$$Q = V \times S \qquad (1)$$

The speed was measured by a magnetic current meter. A graduated ruler and a decametre were used to determine the flow section, which is the product between the mean depth (p) and the width (l) of the watercourse ($S = p \times l$). The gross height of fall (H_b) was determined by the site level (telescope), the GPS and the clisimeter. It is expressed by the relation 2.

$$Hb = A_{am} - A_{av} \quad (2)$$

Where: A_{am} is the altitude upstream of the waterfall and A_{av} is the altitude downstream of the waterfall. In a hydroelectric plant, the potential energy of water stored in a reservoir is converted into kinetic energy by the gravitational flow of water. Then, the kinetic energy of the water is applied to a mechanical component called a turbine that operates an electromechanical generator and the electrical energy is generated by the generator. The gross electrical power (Pb) of the Kalako site is proportional to the flow and the gross head, taking into account the acceleration of the gravity of the waterfall ($g = 9.81 m/s^2$) and the mass volume of water ($\rho = 1000$ kg/m^3). It is expressed by relation 3 (John, 2016).

$$P_b = g \times \rho \times Q \times H_b \quad (3)$$

The useful electrical power (Pu) of the plant takes into account the different hydraulic head losses and those related to the yields of the different machines used. It is determined by relation 4 (Govind, 2016).

$$Pu = \eta \times g \times \rho \times Q \times H_b \quad (4)$$

Where η is the overall yield, which is the product of different machine efficiencies (turbines, couplings, generator, transformer, etc.). This yield is generally between 60 to 90 % (Dimitrios, 2005).

3. Results and Discussions

3.0. Results

The results obtained during this study are shown in Table 1.1.

Table 1.1 *Hydropower characteristics of the Kalako waterfall*

Designation	Symbol	Value	Unit
Flow rate	V	1.46	m/s
Depth of stream	p	0.58	m
Width of the stream	l	17	m
Flow section	S	9.86	m^2
Flow rate	Q	14.40	m^3/s
Altitude upstream of the fall	A_{am}	596	m
Altitude downstream from the fall	A_{av}	536	m
Gross fall height	H_b	60	m
Gross power	P_b	8475.84	kW
Overall yield	η	60	%
Power output	P_u	5085.50	kW

3.1 Discussions

The results obtained during this research show that the hydro-energy potential of the Kalako site on the Tinkisso River is estimated at 5085.50 kW, or about 5.1 MW. This potential lies in the range of mini hydroelectric plants. It is higher than that of the Tinkisso plant, ie 1.65 MW. Thus, the development of this potential would improve the electricity needs of the locality. This potential (5.1 MW) evaluated during the low-water period (January, February, March and April), represents the annual average minimum value of the site's hydro-energy potential. This value is minimal also because we considered the lower bound of the overall yield (60%) of equipment. During the flood season (rainy season), the hydraulic parameters (speed and flow rate) increase, which generates a maximum power output at this time.

4. Conclusion

The hydro-energy potential of the Kalako site evaluated by the point-measurement method during the month of March (low water period) is 5085.50 kW. Such an evaluation campaign and the development of these hydroelectric potentials of all the waterfalls available in the country allows most of the Guinean population to have a guaranteed electricity consumption. This limits the misuse of firewood and charcoal, with a decrease in the release of greenhouse gases into the atmosphere.

Références

[1]. S. Williamson, B. Stark et J. Booker, ''Low head pico hydro turbine selection using a multi-riteria analysis'', Renewable Energy, vol. 61, 43-50. 2014.

[2]. Rapport, ''Bilan Energétique National de la République de Guinée'', Innovation Energie Développement, Système d'Information Energétique-SIE, 35 p. 2015.

[3]. C. C. Mitigation, ''IPCC special report on renewable energy sources and climate change mitigation'', Renewable Energy, 2011.

[4]. K., Sukvipool, C.,Sombatpanit, S. (eds). ''Conservation agriculture in Southeast Asia and beyond''. Special publication 7, World Association

of Soil and Water Conservation (WASWAC), Beijing, China, ISBN 978-0-615-73926-7, 124 p. 2012.

[5]. Kifumbi Francis Mafuta, ''Conception et Modélisation Numérique d'un Simulateur de Mini-Centrale Hydroélectrique Muni des Turbines Francis, Pelton et Cross-Flow pour la Caractérisation des performances et l'étude de la cavitation'', Université Du Québec en Abitibi-Témiscamingue, 127p. 2018.

[6]. Global Water Initiative-Afrique de l'Ouest ''Réflexion stratégique sur la contribution des projets hydroélectriques au développement local durable des zones affectées par les barrages en Guinée'', Rapport final, 131p. 2017.

[7]. Rapport du Ministère de l'Énergie et de l'Hydraulique, ''Présentation du secteur de l'Energie de la République de Guinée'', 28 p. 2012.

[8]. Oumar NDIAYE, ''Etude de la faisabilité de la restauration et de la gestion durable des écosystèmes du haut Tinkisso'', 30p. 2011.

[9]. John. G. Mbaka, Mercy. W. Mwaniki, "Small Hydro-power Plants in Kenya: A Review of Status, Challenges and Future Prospects", Journal of Renewable Energy and Environment, Vol. 3, No. 4, 20-26. 2016.

[10]. Govind R. Joshi, ''Hydroelectric Power Generation and Distribution Planning Under Supply Uncertainty'', Thesis The Department of Engineering Colorado State University-Pueblo, 90 p. 2016.

[11]. Dimitrios A. Géorgakèllos, Les éléments nécessaires pour la gestion d'un projet de microcentrale hydroélectrique Etude de cas d'une PCH en Grèce, Rev. Energ. Ren. Vol. 9, 53-62, 2005)